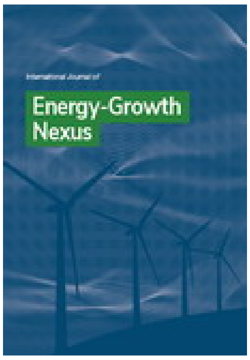

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A sectoral approach to the energy consumption - economic growth nexus for select Asian countries

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A sectoral approach to the energy consumption – economic growth nexus for select Asian countries

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Abstract: Adequate attention has not been paid to understanding the relationship between energy consumption and economic growth at a sectoral level. This study attempts to understand and analyse the relationship between sectoral energy consumption and economic growth for China, India, Indonesia, Malaysia, the Philippines and Thailand by employing techniques such as ARDL bound testing approach to cointegration and Toda Yamamoto causality test. Results suggests that for China and India, industrial energy consumption is cointegrated with economic growth and VECM indicates that it corrects itself after a deviation in the previous period by 31% and 46% resp. Agricultural energy consumption and economic growth are cointegrated for Indonesia and Thailand while variables are cointegrated in the service sector for the Philippines. Toda Yamamoto causality test for China, India, the Philippines and Thailand indicates that agricultural growth causes energy consumption while agricultural energy consumption causes growth in Indonesia and Thailand. Industrial growth causes energy use in India and Philippines while the reverse is in case of China. There exists a bi-directional causality in the service sector for India. In the Philippines, economic growth in the service sector causes energy use, while the reverse is true in Malaysia.

Keywords: energy use; value added; cointegration; causality; agricultural sector; industrial sector; residential sector; service sector.

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Biographical notes: Karen Fernandes earned her PhD from Goa University in 2022 in Energy Economics and is currently working as a Senior Research Associate at the Centre for Excellence in Sustainable Development, Goa Institute of Management one of the top business schools in India. Her research interests include issues related to sustainable development and energy particularly in developing countries.

1 Introduction

The overall growth of an economy is dependent upon the growth and development of various sectors. Energy is a vital input essential for sectoral growth and development. The relationship between energy consumption and economic growth has been extensively analysed by researchers since the oil crises in 1973. Alekhina and Yoshino (2018), Literature in the area of energy economics has gained momentum after a remarkable study undertaken by Kraft and Kraft (1978) who formulated four hypothesis to explain the relationship between energy consumption and economic growth viz. growth hypothesis where energy consumption leads to economic growth, conservative hypothesis where economic growth leads to energy consumption, feedback hypothesis where both variables have an impact or cause either and neutrality hypothesis where there is no relationship between energy consumption and economic growth.

This research paper examines the relationship between energy consumption and economic growth for four sectors of an economy viz. agricultural, industrial, residential and service sector. Numerous researchers have attempted to understand the relationship between energy consumption and economic growth from an aggregate perspective however from the point of view of policy formulation it is important to understand this relationship at a disaggregate level/sectoral level. This is because the growth and development of the sectors of an economy collectively contribute towards its aggregate growth. The growth and development of a sector of an economy is measured by value added which refers to the contribution of that particular sector towards the overall GDP of the country. It is the net output of a sector after adding up all outputs and subtracting intermediate inputs. Understanding the relationship between energy consumption and economic growth at a sectoral level is important to identify which sector is energy dependent so that the economic growth and development of a country is ensured in the long run. This study is conducted keeping in mind SDG 8 which refers to promoting sustained, inclusive and sustainable economic growth. Therefore, examining which sector of each respective economy is energy dependent will aid in determining how energy supply can be made sustainable so the overall growth of the economy is not hampered.

This paper initially elaborates on the background and intent of the study followed by a literature review. The methods used for analysis is then explained and the results of analysis is displayed in section four followed by the findings and conclusion.

2 Literature review

In the domain of energy economics, studies focusing on sectoral energy consumption and economic growth are not conducted extensively. Following are studies identified which have attempted to study energy consumption and economic growth from a sectoral perspective. For Iran, Meidani and Zabihi (2014) examined the causal relationship between real GDP and energy consumption in various economic sectors employing techniques such as the Toda-Yamamoto method, Granger causality test and bound testing and it was concluded that there is a strong unidirectional causality running from energy consumption to real GDP in the industrial sector while (Zamani, 2007) in addition to various sectors , considered different kinds of energy and analysis indicated long-run bidirectional relations between agriculture value added and total energy, electricity and petroleum products consumption in the agricultural sector. Moreover, short-run causality runs from GDP and industrial value added to total energy and petroleum products consumption. A multi-variate sectoral analysis was undertaken in the US by Gross (2012) and it was concluded that there exists a unidirectional long-run causality from growth to energy in the commercial sector and bidirectional causality in the transport sector while another study (Bowden and Payne, 2009) using Toda–Yamamoto long-run causality test found that there exists a bidirectional granger causality between commercial and residential primary energy consumption and real GDP including a causal relationship running from industrial primary energy consumption to real GDP. In addition, Bowden and Payne (2010) examined the causal relationship between renewable and non-renewable energy consumption by sector with real GDP and results indicated a bidirectional granger causality existing between commercial and residential non-renewable energy consumption and real GDP and unidirectional causality from residential renewable energy consumption and industrial non- renewable energy consumption, to real GDP. Kourtzidis et al. (2018) studied the relationship between energy consumption and economic growth both at a country and at a sectorial level for US and it was found that the neutrality hypothesis holds true for all sectors. In Nigeria, Kalu et al. (2019) examined whether any relationship exists between energy consumption and value added of the agricultural and industrial sector as well as the overall growth rate and results indicated that economic growth and agricultural value added adjust to shocks and dynamics of the studied energy-consumption-related variables while manufacturing value added proved otherwise.

In case of India, a study Nain et al. (2017) using ARDL bound test, granger non-causality test and Toda Yamamoto causality test examined the long-run and short-run causal relationships among energy consumption, real GDP and CO_2 emissions. Results indicated that a unidirectional causality runs from energy consumption to GDP for the industrial sector in the short run and in the short and long run for domestic and commercial sectors. Unidirectional causality from energy consumption to CO_2 emission in agriculture and domestic sectors was also identified. Similarly, according to Nath (2020) there exists a unidirectional granger causality from gross value added to electricity consumption in the agricultural and industrial sector. In case of Pakistan, Nadeem and Munir (2016), using ARDL bound testing approach and granger causality test investigated the relationship between energy consumption at aggregate and disaggregate levels in different sectors of the economy with the economic growth and concluded the conservation hypothesis is found in aggregate and disaggregate coal, gas and electricity consumption. Besides, Abbas and Choudhury (2013) studied the causality between electricity consumption and economic growth at aggregated and disaggregated level and results indicated that agricultural GDP causes agricultural electricity consumption. In another study Khan and Younas (2019) applied ARDL bounds testing found that agriculture and manufacturing share has a positive impact on energy while the services sector has a negative effect. In Indonesia, Hutagalung et al. (2019) made an attempt to understand Indonesia’s domestic gas allocation policy and its effects on the national economy and found out that government’s current policy to give priority to oil production is not the optimum way to maximise added value of natural gas to the Indonesian economy while another study Kuhe and Bisu (2019) conducted a review to study the influences of some situational factors on the energy consumption behaviour of households and suggested that there is a need for laws that will encourage energy-saving renovations and provision of recreational facilities in residential areas to reduce in-home energy consumption.

In case of Greece, Tsani (2010) identified a bi-directional causality from real GDP to industrial energy consumption and residential energy consumption after employing Toda-Yamamoto method of grangers causality test while in Tunisia (Abid and Sebri, 2012) using Johansen cointegration and VECM grangers causality test concluded that a unidirectional causality runs from industrial value added to energy consumption in the short-run but the neutrality hypothesis is found in the long-run. Moreover, bidirectional causality between energy use in residential sector and household income is found in the short-run, but a unidirectional causality running from household income to energy consumption in the long-run was identified. Eser Ozen and Hanifi (2018) studied the impact of energy consumption on economic growth on the basis of main sectors of Turkey and concluded that there exists a unidirectional causality from growth to energy consumption in the agricultural sector and bi-directional causality between growth and energy consumption in the service sector. The relationships between aggregated and disaggregated energy use in the industrial sector, carbon emissions and industrial output was examined in China by Fatima et al. (2018) and it was concluded that energy consumption increases CO_2 emission. Besides there exists bidirectional relationships between CO_2 emission, industrial growth and aggregated and disaggregated (coal, oil and natural gas) energy consumption. Similarly in Beijing, Liu et al. (2018) conducted a study to find a detailed quarterly and sectoral nexus between electricity consumption and economic growth. Analysis indicated that primary sector electricity consumption impacts its growth and economic growth of the tertiary sector strongly affects secondary sector while Tan and Tan (2018) studied the causal relationship between real income, energy consumption and carbon dioxide emission in the Malaysian industrial sector using Johansen-Juselius cointegration test and granger causality test and results indicated that there exists a unidirectional causality relationship from energy consumption and CO_2 emissions to real income in both short and long-run. In addition, Nugraha and Osman (2019) concluded that Indonesia value added of industry sector and household final consumption expenditure have a significant effect on the added value of agriculture sector and service sector while added value of agriculture sector increases the added value of service sector. In Cameroon, Tamba (2020) examined the causal relationship between liquefied petroleum gas consumption and economic growth by employing Johansen and autoregressive distributed lag bounds approach to cointegration, Toda Yamamoto causality and Granger causality test and it was concluded that short-run unidirectional causal relationship ranging from LPG consumption to economic growth and causality is found to run from economic growth to LPG consumption in the long run. Chandio et al. (2019) examined the relationship between energy consumption and agricultural economic growth in Pakistan and results indicated that agricultural economic growth is positively affected by gas consumption and electricity consumption. Santillán Vera and de la Vega Navarro (2019) examined if varying household consumption activities at different income levels drove CO_2 emissions to different degrees and results indicated that highest income levels are related to significantly more total CO_2 emissions than the household consumption patterns at the lowest income levels.

Costantini and Martini (2010) studied the causal relationship between economy and energy by adopting a VECM model for non- stationery cointegrated panel data employing techniques such as Pedroni cointegration test and Westurlund test, FMOLS and GMM technique was employed on a panel of countries. However, results indicated that alternative country samples hardly affect the causality relations in a multi-variate multi sector framework. In case of G20 countries a 1% increase in renewable energy consumption raises agriculture, industry, service and overall GDP by 0.342, 0.384, 0.328, and 0.401%, respectively. A 1% raise in non-renewable energy consumption increase economic output of agriculture, industry, service and total GDP by 0.297, 0.376, 0.301, and 0.385%, respectively according to a study by Paramati et al. (2018). In SSA countries, Kalu et al. (2020) investigated into the energy–growth linkage in sub-Saharan Africa (SSA) with emphasis on real sectors' contribution to aggregate growth and found that there is evidence of energy dependence and growth hypothesis. Howarth et al. (2017) assessed the relationship between energy consumption at a sector level and GDP in GCC countries and results indicated that energy consumption and economic growth are strongly linked to all sectors. Narayan and Doytch (2017) studied renewable and non-renewable energy consumption and economic growth nexus using industrial and residential energy for a panel of 89 countries employing System GMM and fixed effects and concluded that residential energy consumption shows growth effects for low and lower-middle-income countries and economic growth has a positive and significant impact on industrial total energy consumption.

Doytch and Narayan (2016) attempted to study the disaggregate FDI inflows into mining, manufacturing, total services, and financial services components and examine the impact of these FDI flows on renewable – and non-renewable industrial energy – sources for 74 countries and concluded the existance of an energy consumption-reducing effect with respect to non-renewable sources of energy and an energy consumption-augmenting effects with respect to renewable energy. Besides, these effects vary in magnitude and significance by sectoral FDI. Another study in Malaysia by Iqbal Hussain et al. (2019), explored the environmental impact of industrial, commercial, transportation and agricultural energy consumption on economic progress by employing ARDL bound testing approach and found positive significant associations of all energy consumptions with economic growth and existence of bi-directional causal association between all sectoral energy consumptions and Malaysian economic progress while Tang et al. (2022) examined the interactions between economic growth, energy prices, technological innovations, and financial depth in Malaysian sectoral energy consumption to conclude that both increases and decreases in energy prices leads to a reduction in industrial energy consumption, but residential and commercial sectors' energy consumption react positively to price falls moreover technological advancement increases transportation energy consumption and both an increase and decrease of credit availability to private sectors reduces industrial energy consumption, however transportation energy consumption reacts positively to financial deepening. In case of Turkey, Karakaya et al. (2020) analysed sectoral convergence in energy consumption to find that industry and transport energy consumption diverge from the mean consumption and, therefore, lead to further increases in energy consumption and energy-related emissions while agriculture and the other sectors, whose consumption per capita values are below the mean, converge towards the mean and this trend is worrying from the sustainability perspective. For Pakistan Asim et al. (2022) estimated the long-term effects of national and international sustainable transport policies on energy consumption and emissions of the road transport sector and advocated that effective electric vehicle (EV) adoption can cause significant reductions in energy/fuel consumption as well as atmospheric emissions.

Further, recent studies have focused on a wide range of issues in the field of energy where Khan et al. (2022) investigates the long-run nexus between green economic growth (GEG) and some factors that determine its behaviour for the OECD and suggested that energy efficiency, renewable energy, and technology as positive predictors of GEG moreover the integrity of the government plays an essential role in implementing more efficient and environmentally friendly production processes. In case of Africa, Lanre Ibrahim et al. (2022) attempted to examine the impacts of structural change, natural resource dependence, environmental technology, and renewable energy in selected five top carbon-emitting African countries and concluded that structural change significantly reduce carbon emissions while environmental technology and renewable energy mitigate the surge in carbon emissions and natural resource dependence induces a substantial increase in carbon emissions. In addition, Omokanmi et al. (2022) probed into the functional association between natural resources, environmental pollution, and longevity in selected resource-dependent African countries with the intervening role of income level and suggested that income significantly promotes longevity, and its interaction with natural resources moderates their adverse effects on longevity. Yu et al. (2023) investigated into the tripartite effects of transportation infrastructure, economic growth, and renewable energy on crude oil imports for China and India and advocated that renewable energy hinders crude oil importation while transportation stimulates it in both economies. The inducing role of economic growth is substantial only in China, and the significant effect of foreign direct investment and industrialisation prove to be fundamental in driving crude oil imports. For China, Wang and Lee (2022) provided a comprehensive assessment of the interrelationships among environmental regulation, clean energy consumption, and economic growth and concluded that regulation enhances the positive effect of clean energy consumption on economic growth, thus prompting provinces to transform onto a clean growth path while Ren et al. (2022) investigate the relationship between economic growth and energy consumption from both time and space perspectives based on panel data from 26 provinces in China and analysis indicated that energy efficiency should be improved in high-carbon development areas, while more attention should be paid to investment and innovations in low-carbon development areas.

There exists limited studies conducted to analyse the relationship between sectoral energy consumption and value added in the Newly industrialised countries of Asia and this study is an attempt to contribute towards this.

3 Methods

To analyse the relationship between energy consumption and economic growth in select sectors of the economy of each country under study, four sectors are identified viz. agriculture, industry, service and residential. Data is obtained form 1990–2018, i.e., a span of 29 years. Data on energy consumption of each select sector is obtained from the International Energy Agency (IEA) and is measured in Terrajoules. Data on economic growth in each sector is measured in term of value added of each select sector and such data is obtained from World Bank Indicators (WBI).

To understand the stationarity properties of the data, unit root test is employed such as Augmented Dickey Fuller (ADF) test, Philips Perron (PP) and Kwiatkowski Phillips Schmidt Shin (KPSS) test. KPSS test checks for stationarity of a series around a deterministic trend where the null hypothesis is that the series is stationary unlike ADF test (Kwiatkowski et al., 1992).

Analysis is sensitive to the lags considered. Therefore, we consider Akaike information criterion (AIC) and Schwarz criterion (SC) and Hannan Quinn (HC) lag selection criteria. ARDL bounds testing approach to cointegration is applied to find out if energy consumption and economic growth are cointegrated in each select sector of the economy of each country. This approach is applicable to variables irrespective of the order of integration however one should ensure that variables are not stationery at second difference. If the F value lies above the critical upper bound then we concluded that the variables are cointegrated. If the F value is below the critical lower bound, then the variables are said to be non-cointegrated and of the F value falls between the upper and lower critical bound, on can concluded that the results are inconclusive. If variables have a long run cointegrating relationship, vector error correction model (VECM) can be applied to find out how quickly variables correct itself towards equilibrium after a deviation in the previous period. To check for causal links between the variables, Toda Yamamoto causality test is employed which can be applied irrespective of the order of integration of the variables under study.

4 Results

4.1 Unit root test

Table 1 indicates stationarity properties of all variables under study. ADF, PP and KPSS unit root test indicate that certain variables exhibit mixed order of integration while most variables indicate stationarity at first difference.

4.2 ARDL bound testing approach to cointegration

Auto regressive distributed lag (ARDL) can be applied to identify cointegrating relationships when variables have a mixed order of integration. The Null Hypothesis states that no long run cointegrating relationship exists while the alternate hypothesis states that long run cointegrating relationship exists. The critical values proposed by Pesaran et al. (2001) which is meant for large sample size can not be applied for small sample sizes. Hence, Narayan (2005) provides a set of critical values for small sample sizes which are 2.496–3.346, 2.962–3.910, and 4.068–5.250 at 90%, 95%, and 99% resp. Since the sample size of this study is small we employ the same. Testing at 5% level of significance, in case of China, there exists a long run cointegrating relationship between energy consumption and economic growth in the industrial sector. The same is with respect to India however in addition to the industrial sector, energy consumption in the residential sector also has a cointegrating relationship with economic growth. In case of Indonesia and Thailand there exists a cointegrating relationship between energy consumption and economic growth in the agricultural sector while for the Philippines, both variables are cointegrated in the agricultural sector.

4.3 Vector error correction model

- China

$$
\begin{aligned}
\mathbf{D(LVA\_INDUSTRY)} = \mathbf{C(1)} * \big(\mathbf{LVA\_INDUSTRY}(-1) & \\
&+ \mathbf{0.0912868772049 * LEC\_INDUSTRY(-1)} \\
&- \mathbf{5.01453570916}\big) \\
&+ \mathbf{C(2) * D(LVA\_INDUSTRY(-1))} \\
&+ \mathbf{C(3) * D(LVA\_INDUSTRY(-))} \\
&+ \mathbf{C(4) * D(LEC\_INDUSTRY(-1))} \\
&+ \mathbf{C(5) * D(LEC\_INDUSTRY(-2)) + C(6)}
\end{aligned}
$$

- India

$$
\begin{aligned}
\mathbf{D(LVA\_INDUSTRY)} = \mathbf{C(1) * (LVA\_INDUSTRY(-1)} \\
&\mathbf{+ 0.00397187461311 * LEC\_INDUSTRY(-1)} \\
&\mathbf{- 3.3917027005\ )} \\
&\mathbf{+ C(2) * D(LVA\_INDUSTRY(-1))} \\
&\mathbf{+ C(3) * D(LVA\_INDUSTRY(-2))} \\
&\mathbf{+ C(4) * D(LVA\_INDUSTRY(-3))} \\
&\mathbf{+ C(5) * D(LEC\_INDUSTRY(-1))} \\
&\mathbf{+ C(6) * D(LEC\_INDUSTRY(-2))} \\
&\mathbf{+ C(7) * D(LEC\_INDUSTRY(-3)) + C(8)}
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{D(LVA\_RESIDENTIAL)} = \mathrm{C(1)} * \big(\mathrm{LVA\_RESIDENTIAL}(-1) \\
&+10.8359605052 * \mathrm{LEC\_RESIDENTIAL}\big(-1\big) \\
&-156.556059228\big) \\
&+\mathrm{C(2)} * \mathrm{D(LVA\_RESIDENTIAL}(-1)) \\
&+\mathrm{C(3)} * \mathrm{D(LVA\_RESIDENTIAL}(-2)) \\
&+\mathrm{C(4)} * \mathrm{D(LEC\_RESIDENTIAL}(-1)) \\
&+\mathrm{C(5)} * \mathrm{D(LEC\_RESIDENTIAL}(-2)) + \mathrm{C(6)}
\end{aligned}
$$

- Indonesia

$$
\begin{aligned}
\mathrm{D(LVA\_AGRICUTURE)} = \mathrm{C(1)} * (\mathrm{LVA\_AGRICUTURE}(-1) \\
&+0.0697543152668 * \mathrm{LEC\_AGRICUTURE}(-1) \\
&-3.26657077145\big) \\
&+\mathrm{C(2)} * \mathrm{D(LVA\_AGRICUTURE}(-1)) \\
&+\mathrm{C(3)} * \mathrm{D(LEC\_AGRICUTURE}(-1)) + \mathrm{C(4)}
\end{aligned}
$$

- Philippines

$$
\begin{aligned}
\mathbf{D(LVA\_SERVICE)} = \mathbf{C(1)} * \big(\ \mathbf{LVA\_SERVICE(-1)} \\
&\mathbf{-2.3464335917 * LEC\_SERVICE(-1)} \\
&\mathbf{-7.42196665554 + C(2) * D(LVA\_SERVICE(-1))} \\
&\mathbf{+ C(3) * D(LEC\_SERVICE(-1)) + C(4)}
\end{aligned}
$$

Table 1 Unit root tests

Country	*Variable*	*ADF unit root*		*PP unit root*		*KPSS uni*
		Level	*1st difference*	*Level*	*1st difference*	*Level*
China	EC agriculture	(2.898)	*(4.885)***	(2.898)	*(7.533)***	0.151
	EC industry	(0.921)	*(2.707)**	(0.719)	*(2.707)**	0.629
	EC residential	(0.399)	*(7.532)***	(0.127)	*(7.181)***	0.163
	EC service	(0.027)	*(3.216)***	(0.665)	*(6.044)***	0.097
	VA agriculture	(2.474)	*(4.261)***	(2.474)	*(4.340)***	0.167
	VA industry	(1.535)	*(3.773)***	(1.591)	*(3.804)***	0.162
	VA residential	(1.882)	*(5.314)***	(1.832)	*(5.441)***	0.147
	VA service	(1.951)	(2.515)	(0.999)	(2.631)	*0.094***
India	EC agriculture	(2.124)	*(3.573)***	(2.251)	*(3.573)***	0.649
	EC industry	(1.696)	*(3.677)***	1.0172	*(3.399)***	0.151
	EC residential	(1.281)	*(2.986)***	(1.246)	*(2.986)***	0.643
	EC service	(1.206)	*(6.904)***	(1.003)	*(6.969)***	0.174
	VA agriculture	(2.517)	*(3.899)***	(1.491)	*(6.667)***	0.131
	VA industry	(2.286)	(2.513)	(1.042)	*(5.281)***	0.111
	VA residential	(0.498)	*(6.048)***	(1.343)	*(6.048)***	0.1840
	VA service	(2.317)	*(5.429)***	(2.508)	*(5.421)***	0.1096
Indonesia	EC agriculture	(1.746)	*(5.779)***	(1.697)	*(5.780)***	0.164
	EC industry	(2.207)	*(7.470)***	(2.207)	*(7.534)***	0.1607
	EC residential	(1.034)	*(2.977)***	(1.077)	*(3.009)***	0.6493
	EC service	3.283	*(3.797)***	(9.9172)	*(4.153)***	0.171
	VA agriculture	(2.135)	*(4.764)***	(2.205)	*(6.995)***	0.637
	VA industry	(0.184)	*(6.927)***	(0.943)	*(8.805)***	*0.1865***
	VA residential	(2.075)	*(16.085)***	(2.279)	*(4.074)***	*0.086***
	VA service	(1.095)	*(3.582)***	(1.373)	*(3.592)***	*0.142***

Notes: *Indicates significance at 10% significance level
**Indicates significance at 5% significance level.

Table 1 Unit root tests (continued)

Country	Variable	ADF unit root		PP unit root		KPSS unit root	
		Level	1st difference	Level	1st difference	Level	1st difference
Malaysia	EC agriculture	(2.769)	*(7.474)***	(2.891)	*(14.548)***	0.162	*0.1190***
	EC industry	(1.712)	*(4.436)***	(1.712)	*(4.437)***	0.1664	*0.069***
	EC residential	(2.138)	*(5.048)***	(2.129)	*(5.045)***	*0.142***	0.078
	EC service	(0.510)	*(5.904)***	(0.220)	*(24.356)***	0.1798	0.481
	VA agriculture	(2.130)	*(5.704)***	(2.042)	*(7.733)***	0.491	*0.4103***
	VA industry	(1.546)	*(6.109)***	(1.528)	*(6.095)***	0.152	*0.083***
	VA residential	(1.834)	*(4.253)***	(2.027)	*(4.148)***	0.6739	*0.092***
	VA service	(3.153)	*(3.950)***	(3.153)	*(3.890)***	0.6800	*0.259***
Philippines	EC agriculture	(1.043)	*(6.879)***	(0.692)	*(7.362)***	0.491	*0.3299***
	EC industry	(2.641)	*(4.970)***	(2.818)	*(6.669)***	0.0783	*0.062***
	EC residential	(3.346)*	(0.924)	(0.099)	(2.202)	*0.1198**	0.1773
	EC service	(1.452)	*(4.018)***	(1.626)	*(3.979)***	0.6642	*0.128***
	VA agriculture	(1.656)	*(4.927)***	(1.789)	*(4.928)***	0.614	*0.094***
	VA industry	(0.993)	*(4.825)***	(1.825)	*(7.152)***	*0.1348***	0.1051
	VA residential	(0.908)	(3.049)	(0.976)	(2.993)	0.165	*0.087***
	VA service	(2.609)	*(4.154)***	(2.516)	*(4.140)***	*0.186***	0.085
Thailand	EC agriculture	(0.876)	*(4.406)***	(1.1305)	*(4.406)***	0.172	*0.099***
	EC industry	(2.457)	*(5.179)***	(2.372)	*(5.034)***	0.156	*0.084***
	EC residential	(0.428)	*(3.666)***	(1.217)	*(3.721)***	0.541	*0.182***
	EC service	(1.996)	*(5.059)***	(1.999)	*(5.075)***	0.168	*0.090***
	VA agriculture	(2.486)	*(5.083)***	(2.486)	*(5.084)***	*0.113***	0.111
	VA industry	(0.898)	*(5.721)***	(1.027)	*(5.668)***	*0.120***	0.124
	VA residential	(1.664)	*(3.378)***	(1.538)	*(3.378)***	0.695	*0.139***
	VA service	1.416	*(3.455)***	3.264	*(3.322)***	0.683	*0.374***

Notes: *Indicates significance at 10% significance level
**Indicates significance at 5% significance level.

- Thailand

$$
\begin{aligned}
D\left(LVA\_AGRICUTURE\right) = {} & C(1)*\left(LVA\_AGRICUTURE(-1)\right. \\
& +1.33200512035*LEC\_AGRICUTURE(-1) \\
& \left.-12.9124803898\right) \\
& +C(2)*D(LVA\_AGRICUTURE(-1)) \\
& +C(3)*D(LVA\_AGRICUTURE(-2)) \\
& +C\left(4\right)*D(LVA\_AGRICUTURE(-3)) \\
& +C\left(5\right)*D(LVA\_AGRICUTURE(-4)) \\
& +C(6)*D(LEC\_AGRICUTURE(-1)) \\
& +C(7)*D(LEC\_AGRICUTURE(-2)) \\
& +C(8)*D(LEC\_AGRICUTURE(-3)) \\
& +C(9)*D(LEC\_AGRICUTURE(-4))+C(10)
\end{aligned}
$$

4.4 Vector error correction model

VECM indicates how rapidly energy consumption is able to correct itself to equilibrium after a deviation in the previous period. Industrial energy consumption of China is able to correct itself after a deviation in the previous period by 31% while industrial energy consumption of India is able to achieve equilibrium after a shock in the previous period to the extent of 45%. However, in the Philippines, energy consumption in the service sector achieves equilibrium after a shock in the previous period to the extent of 1%.

Table 2 ARDL bound testing approach to cointegration

Country	*Sector*	*F -value*	*Result*
China	Agriculture	1.628155	Accept H0
	Industry	8.794203	Reject H0
	Service	1.753527	Accept H0
	Residential	2.494076	Accept H0
India	Agriculture	1.223768	Accept H0
	Industry	6.781303	Reject H0
	Service	0.161960	Accept H0
	Residential	7.225823	Reject H0
Indonesia	Agriculture	5.363867	Reject H0
	Industry	1.830521	Accept H0
	Service	0.136921	Accept H0
	Residential	0.426179	Accept H0
Malaysia	Agriculture	1.458065	Accept H0
	Industry	1.082209	Accept H0
	Service	2.270735	Accept H0
	Residential	0.031767	Accept H0

Table 2 ARDL bound testing approach to cointegration (continued)

Country	*Sector*	*F -value*	*Result*
Philippines	Agriculture	0.197945	Accept H0
	Industry	1.038408	Accept H0
	Service	13.90534	Reject H0
	Residential	1.330623	Accept H0
Thailand	Agriculture	3.520900	Reject H0
	Industry	0.480164	Accept H0
	Service	1.056222	Accept H0
	Residential	2.132199	Accept H0

Table 3 Vector error correction model

Country	*Sector*	*Coefficient*	*Std. error*	*t-statistic*	*Prob.*
China	Industry	(0.312687)	0.076832	(4.069726)	0.0002**
India	Industry	(0.45294)	0.18251	(2.51102)	0.01**
	Residential	0.004472	0.002017	2.217415	0.0323
Indonesia	Agriculture	(0.150312)	0.00406	(1.31779)	0.1941
Philippines	Service	(0.013227)	0.005413	(2.443658)	0.01**
Thailand	Agriculture	(0.068860)	0.082883	(0.830818)	0.4131

Table 4 Toda Yamamoto causality test

	China	*India*	*Indonesia*	*Malaysia*	*Philippines*	*Thailand*
VA agriculture causes EC agriculture	0.0913*	0.0099**	0.2071	0.4420	0.0608*	0.0001**
EC agriculture causes VA agriculture	0.9508	0.3073	0.0780*	0.6927	0.9504	0.0567**
VA industry causes EC industry	0.7816	0.0063**	0.6370	0.9509	0.0157**	0.9885
EC industry causes VA industry	0.0443**	0.3340	0.7622	0.1909	0.7772	0.5780
VA service causes EC service	0.111	0.0258**	0.2009	0.5948	0.1000*	0.3234

Notes: *Significance at 10% level of significance
**Significance at 5% level of significance.

Table 4 Toda Yamamoto causality test (continued)

	China	*India*	*Indonesia*	*Malaysia*	*Philippines*	*Thailand*
EC service causes VA service	0.5698	0.0016**	0.2875	0.0402**	0.8558	0.1810
VA residential causes EC residential	0.3608	0.1598	0.6103	0.1195	0.9678	0.2252
EC residential causes VA residential	0.6943	0.6620	0.4651	0.5532	0.8719	0.8489

Notes: *Significance at 10% level of significance
**Significance at 5% level of significance.

4.5 Toda Yamamoto causality test

To check for causality between energy consumption and economic growth in each sector for the select countries, Toda Yamamoto causality test is applied. In China, India, the Philippines and Thailand, agricultural growth causes its energy consumption. Agricultural energy consumption causes growth in Indonesia and Thailand. Industrial growth causes energy use in India and the Philippines while the reverse is in case of China. There exists a bidirectional causality in the service sector for India. In the Philippines, economic growth in the service sector causes energy use and the reverse in in case of Malaysia.

5 Conclusions

Energy consumption in the industrial sector is cointegrated with economic growth in China according to ARDL bound testing approach and industrial energy consumption is able to correct itself after a deviation in the previous period according to VECM. Growth in the agricultural sector causes energy consumption while energy consumption causes growth in the industrial sector. In case of India, energy consumption and economic growth are cointegrated in the industrial and residential sector however only in the industrial sector, energy consumption achieves equilibrium after a shock in the previous period while growth in the agricultural, industrial and service sector causes its energy consumption which is in line with the findings of a study conducted by Nain et al. (2017).

Energy consumption and economic growth in the agricultural sector in Indonesia is cointegrated however VECM does not indicate a long run relationship. Toda Yamamoto causality test indicates that energy consumption in the agricultural sector causes growth of the sector. For Malaysia, ARDL bounds test does not indicate cointegration between energy consumption and economic growth for all select sectors. Toda Yamamoto causality test indicates that energy consumption causes economic growth only in the service sector. In case of the Philippines, cointegration is found only in the service sector between the energy consumption and economic growth and VECM also indicates that there exists a long run relationship while growth in the agricultural, industrial and service sector causes energy consumption according to Toda Yamamoto causality test. Cointegration exists only in the agricultural sector between energy consumption and economic growth in Thailand however VECM does not indicate a long run relationship. A bi-directional causality exists between energy consumption and economic growth only in the agricultural sector.

The Industrial sector of China supports the growth hypothesis where energy consumption leads to growth of the sector, i.e., the sector is energy dependent (Hu et al., 2015) while the conservative hypothesis holds true in case of the agricultural, industrial and service sector of India and the Philippines where growth leads to energy consumption. Similar to China, energy consumption of Indonesia, in the agricultural sector causes growth of the sector and growth hypothesis hold true for the service sector in case of Malaysia. Since the year 1990, energy consumed by the newly industrialised countries to a great extent is by the industrial and service sector as compared to the residential and agricultural sector besides the service sector and industrial sector have been major contributors to the GDP of these countries.

Therefore, in case of India and the Philippines where growth in the industrial sector causes energy consumption, efforts should be made that these countries rely on renewable energy and the same is in the case of the service sector of the Philippines. Besides, industrial energy consumption of China causes industrial value added which implies that the industrial sector is energy-dependent and therefore use of non-conventional energy will ensure sustainable growth of the industrial sector. Similarly, the growth of the service sector of Malaysia is energy dependent requiring the country to promote reliance on renewable sources to prevent environmental degradation and secure sustainable growth and development of Malaysia. This study is restricted to four sectors however there may be other sectors of the economy such as transportation which can be considered for future research. Further studies can be conducted for a single sector to delve deeper into the relationship between energy consumption and economic growth instead of a multi-sectoral approach.

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